FISH AS DIET OF THE BLUE-EYED SHAG, *PHALACROCORAX ATRICEPS BRANSFIELDENSIS* AT HALF-MOON ISLAND, SOUTH SHETLAND ISLANDS

by

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ABSTRACT. - Thirty eight regurgitated casts collected in a colony at Half-moon Island, South Shetland Islands, during January and February 1993, were analyzed to determine the importance of fish in the diet of the blue-eyed shag *Phalacrocorax atriceps bransfieldensis*. Fish species were identified by means of otoliths found in the casts. The size and weight of the fish were estimated from the otolith lengths, using equations derived from data on local populations. Fish remains were present in all casts, comprising 91% of prey items. From the 937 otoliths found, 562 fish were represented and 524 were assigned to 5 demersal benthic species: *Nototheniops nudifrons, Harpagifer antarcticus, Trematomus newnesi, Notothenia coriiceps* and *Gobionotothen gibberifrons*. *N. nudifrons* was the most frequent (68.4%) and important by number (37.9%), whereas *N. coriiceps* prevailed in mass (35.8%). With the exception of *G. gibberifrons*, the fish species (and their size and age ranges) were identical to those found in a similar study at Duthoit Point, Nelson Island. However, the relative importance of the fish species in the diet differed between shags from the two areas.

RÉSUMÉ. - Trente-huit échantillons de régurgitats du Cormoran aux yeux bleus *Phalacrocorax atriceps bransfieldensis* collectés entre janvier et février 1993, ont été analysés pour déterminer l'importance des poissons dans le régime alimentaire. Les espèces de poissons ont été identifiées à l'aide des otolithes trouvés dans les régurgitats. La taille et le poids des poissons ont été obtenus à partir d'équations établies à partir de la relation entre la longueur des otolithes et ces mêmes valeurs sur des populations locales. Les poissons représentent 91% des proies dans l'échantillon. 937 otolithes représentent 562 poissons dont 524 proviennent de 5 espèces bentho-démersales: *Nototheniops nudifrons, Harpagifer antarcticus, Trematomus newnesi, Notothenia coriiceps* et *Gobionotothen gibberifrons*. *N. nudifrons* est la proie la plus fréquente (68,4%) et la plus importante en nombre (37,8%) tandis que *N. coriiceps* domine en poids (35,8%). A l'exception de *G. gibberifrons*, les espèces des poissons, les gammes de taille et d'âge sont les mêmes que celles qui ont été trouvées dans une étude comparable à Duthoit Point, île Nelson. Des différences sont observées en ce qui concerne l'importance relative des espèces dans le régime alimentaire.

Key-words. - Fish as diet, Cormorant, PS, Antarctica, South Shetlands Islands, Pellets.

In marine ecosystems, the predator-prey interaction between birds and fish plays an important role in the structure and dynamics of the trophic web. The fish prey of most seabirds species are pelagic or pelagic stages of demersal-benthic fish, caught close to the surface (Furness, 1978; Croxall *et al.*, 1984; Montevecchi and Berruti, 1991). Studies on the diet of the blue-eyed shag *Phalacrocorax atriceps* indicate that this is the only flying bird in the Antarctic that feed chiefly on benthic fish (secondarily also on polychaetes, mollusks and crustaceans) diving to the bottom close inshore (see Schlatter

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and Moreno, 1976; Blankley, 1981; Shaw, 1984; Brothers, 1985; Espitalier-Noel *et al.*, 1988; Green *et al.*, 1990a, b; Wanless *et al.*, 1992; Casaux and Barrera-Oro, 1993). The diving patterns and performance showing its foraging behaviour have been well described in recent years (Croxall *et al.*, 1991; Kato *et al.*, 1991; Wanless *et al.*, 1992). The fish taken by antarctic penguins are mostly pelagic, only the gentoo (*Pygoscelis papua*) feeds inshore alternatively on pelagic and benthic species (Brown *et al.*, 1990; Bost *et al.*, 1994).

Barrett (1991), in his study on the diet of *Phalacrocorax aristotelis* at the Norwegian coasts, suggested the use of shags as a potential method for supplementing fish surveys of littoral species difficult to sample. A recent study on the diet of *Phalacrocorax atriceps bransfieldensis* at Nelson Island, South Shetland Islands, showed that the fish species represented in regurgitated casts agreed qualitatively and in relative numbers with those regularly sampled with trammel-nets in the same area (Casaux and Barrera-Oro, 1993). We suggested that a long term program evaluating the diet and breeding performance of the blue-eyed shag could help to monitor coastal fish populations. Consequently, we consider of present interest the continuity of these studies in the South Shetland Islands area.

This paper presents information on the diet of breeding *P. a. bransfieldensis* from Half-moon Island, thus complementing the data recently published for Duthoit Point, Nelson Island (Casaux and Barrera-Oro, 1993).

MATERIAL AND METHODS

Thirty eight regurgitated casts of *P. a. bransfieldensis* were collected in a colony at Half-moon Island (62°36'S, 59°55'W), South Shetland Islands, during January and February 1993 (Fig. 1).

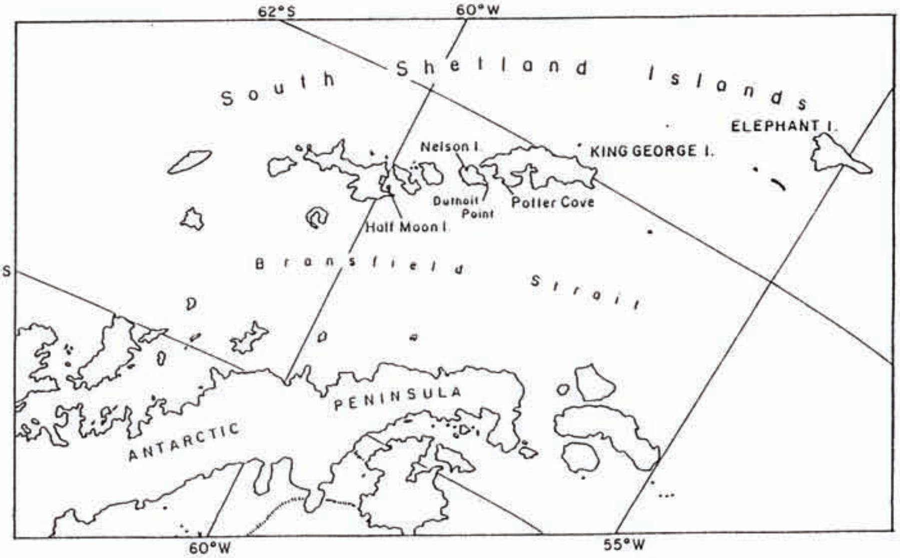

Fig. 1. - Location of Half-moon Island at the South Shetland Islands.

The casts were frozen and shipped to Buenos Aires for analysis. At the laboratory, they were dried to constant weight at 60°C. Using a light microscope, the contents were identified and sorted into prey classes. The otoliths recovered were cleaned and assigned, where possible, to species level. For this task we used descriptions and illustrations of North *et al.* (1984), Hecht (1987), Williams and McEldowney (1990) and our own reference collection. To estimate the number of fish of each species present per cast, the otoliths were sorted into right and left, and the highest value used. Equations derived from otolith length (OL), were used to estimate total length (TL) and weight of the fish identified. These values were corrected by assuming a reduction in otolith lengths by digestion of 5% (Croxall *et al.*, 1988; Casaux and Barrera-Oro, 1993). Equations were:

Nototheniops nudifrons (2)

$TL = 32.95*OL^{1.05}$ mm (n = 46)

$SL = 33.78*OL^{0.96}$ mm (n = 11)

$Weight = 4.01*10^{-7}*SL^{3.81}$ g (n = 11)

Harpagifer antarcticus (3)

$TL = 3.268603+1.812654*OL$ cm (n = 124)

$Weight = -123.1464*TL^{-0.5804228}+45.39072$ g (n = 124)

Trematomus newnesi (3)

$TL = 1.568699+4.166653*OL$ cm (n = 84)

$Weight = 0.146477*TL^{2.127549}$ g (n = 77)

Notothenia coriiceps (3)

$TL = -11.4918+11.31757*OL$ cm (n = 161)

$Weight = 0.0032*TL^{3.4407}+25.439$ g (n = 501)

Gobionotothen gibberifrons (2)

$TL = 17.64*OL^{1.468}$ mm (n = 85)

$Weight = 2.98*10^{-6}*TL^{3.2}$ g (n = 78)

RESULTS

The analysis of the 38 regurgitated casts, showed that fish were by far the most frequent food item, comprising 91.2% by number of all prey individuals. Trochiid gastropods were the second most common prey (F = 26.3%). Other less important items were octopods, bivalves and limpets. Stones, algae and feathers were well represented, but not considered as food (Table I).

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(2) Taken from Hecht (1987). Data from fish collected at Elephant Island, South Shetland Islands and South Georgia Islands.

(3) Calculated using unpublished fish data from Potter Cove. The age ranges of the fish species were calculated using age-length relationships taken from the literature (Tomo and Cordero Funes, 1972; Clasing *et al.*, 1985; Radtke *et al.*, 1989; Radtke and Hourigan, 1990) and from our unpublished data.

Table I. - Diet composition of *Phalacrocorax atriceps bransfieldensis* at Half-moon Island as shown by the contents of 38 castings.

	Freq.	Freq.%	N	N%
Algae	17	44.74	17	2.76
Mollusks				
Gastropods				
Trochidae (shell)	10	26.32	15	2.44
Limpets (shell)	2	5.26	8	1.30
Bivalves (shell)	3	7.89	6	0.98
Octopods (beaks)	4	10.53	7	1.14
Fish (bones-otoliths)	38	100.00	562	91.38
Others				
Stones	26	68.42	-	-
Feather	22	57.89	-	-

Table II. - Comparison between the fish species represented in pellets of *Phalacrocorax atriceps bransfieldensis* from Half-moon Island and Duthoit Point, Nelson Island, South Shetland Islands. (1): Radtke and Hourigan, 1990; (2): Radtke *et al.*, 1989; (3): Tomo and Cordero Funes, 1972; (4): Barrera-Oro and Casaux, unpubl. data; (5): Clasing *et al.*, 1985.

	Half-moon Island, N = 562				
	Freq. %	N° %	Mass %	Size range (cm)	Age range (years)
Nototheniops nudifrons	68	38	29	5.7 - 18.6	1 - 9 (1)
Trematomus newnesi	58	24	16	2.8 - 15.2	0 - 3 (2)
Harpagifer antarcticus	42	24	7	5.1 - 9.6	1 - 4 (3)
Notothenia coriiceps	34	4	36	11.4 - 33.7	1 - 6 (4)
Gobionotothen gibberifrons	24	4	13	8.5 - 33.5	1 - 10 (5)
Unidentified / broken	55	7	-	-	-
	Duthoit Point, Nelson Island, N = 1219				
Nototheniops nudifrons	22	3	3	3.0 - 15.1	0 - 8 (1)
Trematomus newnesi	24	2	2	8.1 - 12.5	1 - 2 (2)
Harpagifer antarcticus	92	87	29	5.2 - 9.2	1 - 4 (3)
Notothenia coriiceps	64	5	66	6.2 - 33.1	1 - 6 (4)
Gobionotothen gibberifrons	-	-	-	-	-
Unidentified / broken	28	4	-	-	-

Nine hundred and thirty seven otoliths occurred in 33 pellets, presumably from 562 fish; 524 were identified as belonging to 5 species: *Nototheniops nudifrons, Harpagifer antarcticus, Trematomus newnesi, Notothenia coriiceps* and *Gobionotothen*

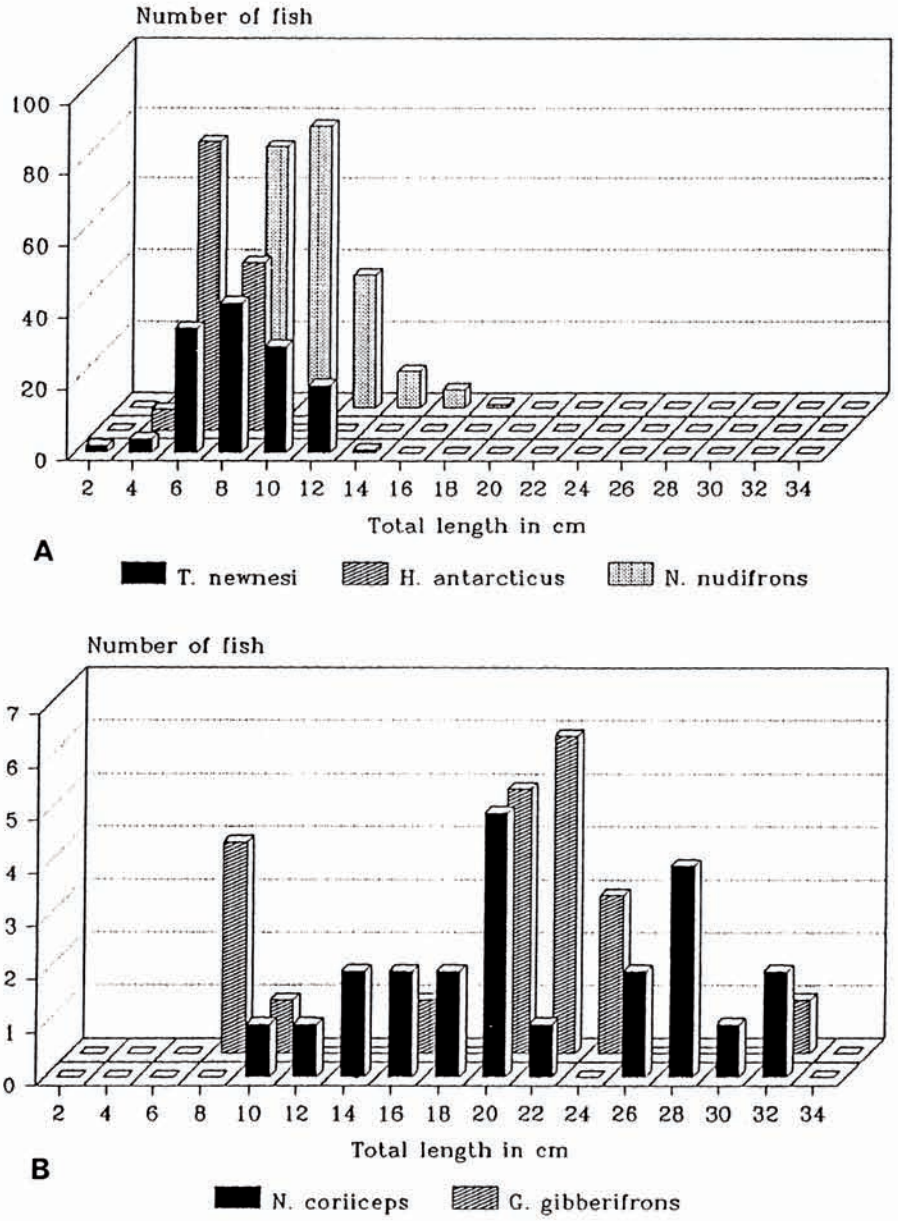

Fig. 2. - Length frequency distribution (calculated from otolith lengths) of fish prey: A) *Nototheniops nudifrons*, *Trematomus newnesi* and *Harpagifer antarcticus*; B) *Notothenia coriiceps* and *Gobionotothen gibberifrons*.

gibberifrons. *N. nudifrons* was the most abundant (38% by number) and constituted 29% by estimate mass of the fish diet (Table II).

Despite being poorly represented numerically (4.1%), *N. coriiceps* was the most important fish species by weight (35.8%). According to the size estimated for each species, *T. newnesi* (TL = 2.8 cm) and *N. coriiceps* (TL = 33.7 cm) were the smallest and the largest respectively (Fig. 2, Table II). The heaviest estimated mass of fish present in a single cast was 898 g, comprising two *N. coriiceps* specimens. The maximum number of fish represented in a cast was 41 (22 *H. antarcticus*, 9 *N. nudifrons*, 5 *T. newnesi*, 3 *G. gibberifrons* and 2 unidentified). For all the species, the age ranges indicated that both young and adult specimens occurred in the diet (Table II).

DISCUSSION

As was reported for *Phalacrocorax atriceps* at other localities (Schlatter and Moreno, 1976; Blankley, 1981; Shaw, 1984; Brothers, 1985; Espitalier-Noel *et al.*, 1988; Green *et al.*, 1990a, b; Casaux and Barrera-Oro, 1993), demersal-benthic fish were the main prey of *P. a. bransfieldensis* at Half-moon Island, during the breeding season (Table I). With the exception of *Gobionotothen gibberifrons*, which was found only in the present study, all the fish species agreed (even in the estimated size and age ranges) with those found in casts collected at a nearby locality, Duthoit Point, Nelson Island (Casaux and Barrera-Oro, 1993) (Table II). However, the importance of those species in the diet varied between shags from the two areas. Whereas *Nototheniops nudifrons* and *Trematomus newnesi* were poorly represented at Duthoit Point (together 5% by number and mass), they were more important at Half-moon Island (together 62% by number, 45% by mass). The importance of *Harpagifer antarcticus* diminished considerably whereas *Notothenia coriiceps* remained as the main species by weight (Table II). The opportunistic feeding behaviour of shags suggests that the proportionate composition of its diet will vary according to the local prey availability.

The other groups represented in the diet (all of them mollusks) were basically the same as found in casts collected at Duthoit Point, but in different proportions (Table I).

Seaweed, which occurred in the casts with a frequency of 45%, is the main item used by shags for nest building purposes (Schlatter and Moreno, 1976; Bernstein and Maxson, 1982; Green *et al.*, 1990a). Previously, we suggested that they are ingested accidentally during transport to the nest (Casaux and Barrera-Oro, 1993). However, data from a recent feeding experiment on captive *P. a. bransfieldensis* showed that the algae found in the casts had been originally eaten by fish (Casaux *et al.*, 1994). Moreover, *N. coriiceps*, which ingest algae regularly (Arnaud and Hureau, 1966; Daniels, 1982; Barrera-Oro and Casaux, 1990) was the main fish species used to feed the shag.

The presence of stones in shag's pellets has been extensively discussed (Van Tets, 1967; Schlatter and Moreno, 1976; Casaux and Barrera-Oro, 1993). One possibility is that stones may be taken accidentally while shags feeds on benthic prey (Casaux and Barrera-Oro, 1993). Interestingly, the high frequency of stones present in all samples found in casts collected at Duthoit Point fell markedly in the present study (68% of samples) in parallel with the reduced presence (92% to 42%) of *H. antarcticus* (which lives in rubble bottoms) in the shag's diet.

Although the analysis of pellets has been widely used to identify the diet components of piscivorous birds, difficulties and limitations of this method have been pointed out (see Jobling and Breiby, 1986). Duffy and Laurenson (1983) and Johnstone *et al.* (1990) reported that the examination of pellets of captive Cape cormorants

(*Phalacrocorax capensis*) and captive European shags (*P. aristotelis*) respectively, underestimated the number and the sizes of fish taken. Although such conclusions were based on shag and fish species different to those in our studies (e.g., Casaux and Barrera-Oro, 1993), we were aware of the need to be cautious with the interpretation of results. The results of the feeding trial on *P. a. bransfieldensis* fed with local fish species (Casaux *et al.*, 1994) showed that the otoliths of *G. gibberifrons* were the less affected by the digestive process, while those of *Notothenia rossii* were later largely underrepresented in number and size in the regurgitated casts. This is not unexpected, since in the former species the otoliths are fairly large and solid, whereas in the latter they are smaller and brittle and therefore much more subject to erosion and loss.

In the same experiment, *P. a. bransfieldensis* produced pellets after an average food intake of 659 g of fish per day (Casaux *et al.*, 1994). This daily consumption is in line with the range of 600-1209 g estimated by Shaw (1984) and Bernstein (1982) (quoted in Shaw, 1984) respectively. Moreover, even the estimated maximum mass of fish represented by a single cast in this study (898. 2 g) which also agreed with that reported for blue-eyed shags at Duthoit Point (983 g), is well within the range. The calculated size and age ranges of the fish are also very similar (Table II). Although shags have benthic feeding habits, the smaller specimens of some of the fish species represented in the casts are pelagic. It was suggested that those fish are taken in the intertidal zone, including tide pools (Casaux and Barrera-Oro, 1993), and this was recently confirmed by direct observation in the wild (R. Casaux and M. Favero, pers. obs.). The composition of nearshore fish communities is often very well reflected in the composition of regurgitated casts of cormorants occurring in the same area (Duffy and Laurenson, 1983; Duffy *et al.*, 1987; Wanless *et al.*, 1992; Casaux and Barrera-Oro, 1993). In Antarctica, for instance, the depth distribution of littoral fish is completely included in the blue-eyed shag foraging depth range (down to 116 m, according to Croxall *et al.*, 1991). It has been suggested that shags could potentially be used as biological samplers capable of reflecting diversity and changes in the abundance of littoral fish populations (Ainley *et al.*, 1981; Duffy and Laurenson, 1983; Duffy *et al.*, 1987; Barrett, 1991; Wanless *et al.*, 1991; Casaux and Barrera-Oro, 1993). However, as shown above, the analysis of pellets may provide biased results if no concomitant studies are being conducted to estimate correction factors by fish species which account for the erosion and loss of otoliths (see Hartley, 1948).

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REFERENCES

AINLEY D., ANDERSON D. & P. KELLY, 1981. - Feeding ecology of marine cormorants in southwestern North America. *Condor*, 83: 120-131.

ARNAUD P. & J. HUREAU, 1966. - Régime alimentaire de trois Téléostéens Nototheniidae antarctiques (Terre Adélie). *Bull. Inst. Océanogr.* Monaco, 66: 1-24.

BARRERA-ORO E. & R. CASAUX, 1990. - Feeding selectivity in *Notothenia neglecta*, Nybelin, from Potter Cove, South Shetland Islands, Antarctica. *Antarct. Sci.*, 2(3): 207-213.

BARRETT R., 1991. - Shags (*Phalacrocorax aristotelis* L.) as potential samplers of juvenile Saithe (*Pollachius virens* (L.)) stocks in northern Norway. *Sarsia*, 76: 153-156.

BERNSTEIN N. & S. MAXSON, 1982. - Behaviour of the Antarctic Blue- eyed Shag *Phalacrocorax atriceps bransfieldensis*. *Notornis*, 29: 197-207.

BLANKLEY W., 1981. - Marine food of kelp gulls, lessersheathbills and imperial cormorants at Marion Islands (Subantarctic). *Cormorant*, 9: 77-84.

BOST C., KOUBBI P., GENEVOIS., RUCHON L. & V. RIDOUX, 1994. - Gentoo penguin *Pygoscelis papua* diet as an indicator of planktonic availability in the Kerguelen Islands. *Polar Biol.*, 14: 147-153.

BROTHERS N., 1985. - Breeding biology, diet and morphometrics of the King Shag, *Phalacrocorax albiventer purpurascens*, at Macquarie Island. *Austr. Wildl. Res.*, 12: 81-94.

BROWN C., KLAGES N. & N. ADAMS, 1990. - Short and medium-term variation in the diets of penguins at Marion Islands. *South Afr. J. Antarct. Res.*, 20(1): 13-20.

CASAUX R. & E. BARRERA-ORO, 1993. - The diet of the blue-eyed Shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait. *Antarct. Sci.*, 5(4): 335-338.

CASAUX R., FAVERO M., BARRERA-ORO E. & P. SILVA, 1994. - Preliminary results of a feeding trial on the blue-eyed shag *Phalacrocorax atriceps*. Document WG-CEMP-94/29. CCAMLR, 14 p., Hobart, Australia.

CLASING E., WHITE M. & C. MORENO, 1985. - Estudio de la edad en una población virginal de *Notothenia gibberifrons* (Pisces: Nototheniidae) de Bahía South, Antártica. *Ser. Cient. Inst. Antárt. Chileno*, 32: 75-90.

CROXALL J., RICKETTS C. & P. PRINCE, 1984. - Impact of seabirds on marine resources, especially krill, of South Georgia waters, pp. 285-317. *In:* Seabird Energetics (Whittow G.C. & H. Rahn, eds). New York: Plenum Press.

CROXALL J., NORTH A. & P. PRINCE, 1988. - Fish prey of the Wandering Albatross *Diomedea exulans* at South Georgia. *Polar Biol.*, 9: 9-16.

CROXALL J., NAITO Y., KATO A., ROTHERY P. & D. BRIGGS, 1991. - Diving patterns and performance in the Antarctic blue-eyed shag *Phalacrocorax atriceps*. *J. Zool., Lond.*, 225: 177-199.

DANIELS R., 1982. - Feeding ecology of some fishes of the Antarctic Peninsula. *Fish. Bull. US*, 80: 575-588.

DUFFY D. & L. LAURENSON, 1983. - Pellets of Cape Cormorants as indicators of diet. *Condor*, 85: 305-307.

DUFFY D., WILSON R. & M. WILSON, 1987. - Spatial and temporal patterns of diet in the Cape Cormorant off southern Africa. *Condor*, 89: 830-834.

ESPITALIER-NOEL G., ADAMS N. & N. KLAGES, 1988. - Diet of the Imperial Cormorant *Phalacrocorax atriceps* at sub-Antarctic Marion Island. *Emu*, 88: 43-46.

FURNESS R., 1978. - Energy requirements of seabird communities: a bioenergetic model. *J. Anim. Ecol.*, 47, 39-43.

GREEN K., WILLIAMS R. & D. SLIP, 1990a. - Diet of the Macquarie Island Cormorant *Phalacrocorax atriceps purpurescens*. *Corella*, 14(2): 53-55.

GREEN K., WILLIAMS R., WOEHLER E., BURTON H., GALES N. & R. JONES, 1990b. - Diet of the Heard Island cormorant *Phalacrocorax atriceps nivalis*. *Antarct. Sci.*, 2(2): 139-141.

HARTLEY P., 1948. - The assessment of the food of birds. *Ibis*, 90: 361-381.

HECHT T., 1987. - A guide to the otoliths of Southern Ocean fishes. *South Afr. J. Antarct. Res.*, 17: 1-87.

JOBLING M. & A. BREIBY, 1986. - The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. *Sarsia*, 71: 265-274.

JOHNSTONE I., HARRIS M., WANLESS S. & J. GRAVES, 1990. - The usefulness of pellets for assessing the diet of adult Shags *Phalacrocorax aristotelis*. *Bird Study*, 37: 5-11.

KATO A., CROXALL J., WATANUTI Y. & Y. NAITO, 1991. - Diving patterns and performance in male and female blue-eyed cormorants *Phalacrocorax atriceps* at South Georgia. *Mar. Ornithol.*, 19: 117-129.

MONTEVECCHI W. & A. BERRUTI, 1991. - Avian bioindication of pelagic fishery conditions in the southeast and northeast Atlantic, pp. 2246-2256. *In:* Acta XX Cong. Int. Ornithol.

NORTH A., BURCHETT M., GILBERT C. & M. WHITE, 1984. - Identification of fish from the Southern Ocean by means of otoliths. *Br. Antarct. Surv. Bull.*, 62: 83-94.

RADTKE R., TARGETT T., KELLERMANN A., BELL J. & K HILL, 1989. - Antarctic fish growth: profile of *Trematomus newnesi. Mar. Ecol. Prog. Ser.*, 57: 103-117.

RADTKE R. & T. HOURIGAN, 1990. - Age and growth of the Antarctic fish *Nototheniops nudifrons. Fish. Bull.*, 88(3): 557-571.

SCHLATTER R. & C. MORENO, 1976. - Hábitos alimentarios del cormorán antártico, *Phalacrocorax atriceps bransfieldensis* (Murphy) en Isla Green, Antártida. *Ser. Cient. Inst. Antárt. Chileno*, 4(1): 69-88.

SHAW P., 1984. - Factors affecting the breeding performance of the Antarctic Blue-eyed Shag (*Phalacrocorax atriceps bransfieldensis*). Ph. D. thesis, Univ. Durham.

TOMO A. & J. CORDERO FUNES, 1972. - Edad y crecimiento en largo del *Harpagifer bispinis antarcticus. Contrib. Inst. Antárt. Argent.*, 96: 19 p.

VAN TETS G., 1967. - White-breasted Cormorant swallows pebbles on land. *Emu*, 67(3): 224.

WANLESS S., HARRIS M. & J. MORRIS, 1991. - Foraging range and feeding locations of Shags *Phalacrocorax aristotelis* during chick rearing. *Ibis*, 133: 30-36.

WANLESS S., HARRIS M. & J. MORRIS, 1992. - Diving behaviour and diet of the blue-eyed shag at South Georgia. *Polar Biol.*, 12: 713-719.

WILLIAMS R. & A. MCELDOWNEY, 1990. - A guide to the fish otoliths from waters off the Australian Antarctic Territory, Heard and Macquarie Islands. *ANARE Res. Notes*, 75: 1-173.

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